THE GROWTH OF CORAL REEFS.

A LECTURE BY PROFESSOR AGASSIZ.

[Reported for the Scientific American.]

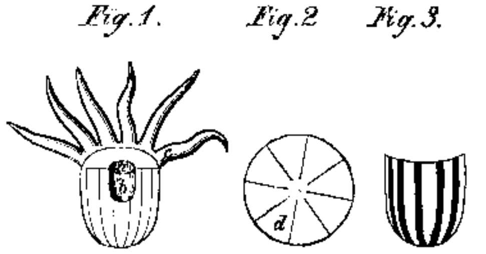
On Sunday evening, Feb. 2, Prof. Agassiz delivered the third lecture of his course on the goodness and wisdom of God, as manifested in his works. In this course he draws his illustrations from the science of zoology. In his first lecture he explained that the animals of the globe are divided into four orders, the simplest and lowest of which is the order of the Radiata. In these animals the parts radiate from a central vertical axis, like the spokes of a wheel which lies in a horizontal position. Of the three principal classes of radiates the lowest is the class of polyps, and the most interesting sample of these is that wonderful animal that builds the coral reefs. On being introduced the lecturer said :—

Accustomed to the narrow walls of a lecture room, I have never addressed an audience like this ; and if I should not succeed in expanding my voice so as to be heard in the remotest parts of the building, I desire to apologize in advance.

A question which excited the greatest interest a few years since, was in relation to the time at which animals first made their appearance on this earth. It was formerly supposed that we knew exactly how many years had elapsed since all animals were created, but on examination it is found that the chronology of Genesis relates only to man, and we now know that the lower orders of animals existed long before man was created. I will give you an account this evening of the animals that build the coral reefs, and will present some facts indicating the periods during which they have been at work.

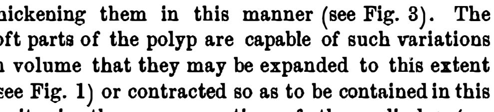
Coral is not the shell of an animal, but it forms the hard part of his body, just as much as our bones are parts of our bodies. If any of you have seen the jelly-like animal that floats about the docks of our harbors—the Sea Anemone—you can form a very good idea of the animal which I am going to describe.

Fig. 1. Fig. 2 Fig. 3.



I will draw a rough representation of the coral animal upon the blackboard (see Fig. 1). These (*c*) are the tentacula, this (*a*) is the mouth, this (*b*) is the digestive cavity. These thin divisions (*d*) radiate from the center as shown in this cross section (Fig. 2); this structure placing the animal in the order of the Radiata, the lowest of the four orders ; and it belongs to the lowest class in this order—the polyps. These tentacula are furnished with numerous minute hairs or cilia, which by their motion create a current of water into the mouth of the polyp, and thus draw in its food. The carbonate of lime which forms the durable part of the animal—the part with which we are all familiar—is drawn in by the animal with its food, and is secreted by its organs and deposited on the outer wall of its body and on these radiating divisions ; thickening them in this manner (see Fig. 3). The soft parts of the polyp are capable of such variations in volume that they may be expanded to this extent (see Fig. 1) or contracted so as to be contained in this cavity in the upper portion of the cylinder (see Fig. 3).

Coral reefs are built in this form. The horizontal line represents the surface of the water, and this lower line the bottom of the sea sloping downward from



the shore. The reef you see is nearly vertical on the sea side, and considerably inclined on the side next the land. They are always commenced in water from 10 to 12 fathoms in depth, never more than 72 feet, never less than 60.

This statement may seem to conflict with that of Capt. Cook, that he brought up corals in the Pacific Ocean from a depth of 2,000 feet. But, though I have no doubt of the truth of Capt. Cook's statement, and though I know that mine is correct, there is no conflict between them. It is ascertained that the bottom of the Pacific Ocean is subsiding, and we know the direction of the subsidence. The corals that Capt. Cook recovered from so great a depth were the limestone remains of animals that had long been dead. They grew at the usual proximity to the surface, and were carried down with the settling of the ocean bed.

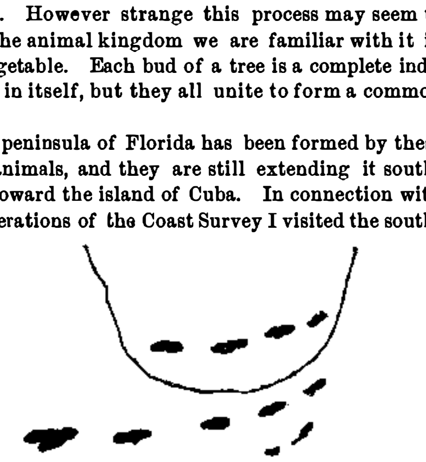
There are several species of corals, and each lives at a certain depth beneath the surface ; being unable to exist either above or below the zone for which it is adapted. This is not strange when we consider the very soft character of its body, and the rapidity with which the pressure of water increases with the depth. At the surface there is a pressure of one atmosphere, at a depth of 32 feet a pressure of two atmospheres, and at a depth of 64 feet a pressure of three atmospheres, and this is as great a pressure as any of these animals can bear.

Each coral reef is built by four species of polyps ; the bottom being constructed by the species which lives at the greatest depth, and the several parts above by species inhabiting corresponding strata of water. The reef builder lays the foundation at the base of the outer wall ; and the growth is more rapid there than it is in the parts nearer the land. For this polyp is adapted to clean sea water, and will not live in the foul water inside the reef. The reef, therefore, soon assumes a form similar to that which it has in its finished state—the form indicated in the drawing. When the species of polyp that lives in water of 10 or 12 fathoms in depth has carried the structure up through the zone which it inhabits, his labors cease, and the work is continued by a second species. As this species does not require water so pure as the first he extends his growth toward the shore, thus sloping the reef as represented. Having grown upward through his stratum of water, his growth ceases, and a third and fourth species complete the reef.

It was at one time a mystery to us that one species could thus apparently grow out of another. But, in examining the mode of reproduction of these polyps, I discovered facts which explained the mystery. Though the mature animal is attached immovably to the rock, when first hatched he swims through the water, and is confined to the same stratum of depth as in the matured state. When swimming about in this undeveloped state, if he encounters the upper surface of a coral reef which has grown up to his stratum of water, he attaches himself to it and then begins to grow ; thus continuing the structure.

These polyps multiply and grow by a process of budding. A protuberance appears upon one side of the body, which finally develops into a perfect animal ; but is not separated from the parent, making a compound animal of numerous individuals united together. However strange this process may seem to us in the animal kingdom we are familiar with it in the vegetable. Each bud of a tree is a complete individual in itself, but they all unite to form a common plant.

The peninsula of Florida has been formed by these little animals, and they are still extending it southward toward the island of Cuba. In connection with the operations of the Coast Survey I visited the south-



ern part of Florida to examine the coral reefs, and I made some efforts to ascertain the rate of their growth. The foundations of Fort Jefferson, on Tortugas Island, and of Fort Taylor, at Key West, showed that the reefs had risen one inch in fourteen years. This would give in round numbers, after allowing for inaccuracies, say one foot in a century. This is doubtless more rapid than the actual growth, as the mass near the bottom is crushed together and compressed by the superincumbent weight, and it would probably take at least two centuries to grow one foot. But calling it one foot in a century it would take a reef sixty centuries, or six thousand years, to rise from a depth of sixty feet to the surface.

Let this indicate the outline of the southern end of Florida. Nearly parallel with the coast, diverging from it toward the west, is a row of small islands, called keys, and beyond these again a row of still smaller islands, which are called coral reefs. On examining the keys, too, they are found to be reefs of coral. Now, as the reef-building polyps can live only in the clean sea water, and perish if brought into the muddy water inside the reefs, we come to the conclusion that the keys were built up before the outer reefs were commenced. And if we allow the same rate of growth for them, their foundations must have been laid at least 12,000 years ago.

Along the coast is a marshy tract of land called the Indian Hunting Grounds, and beyond this, still parallel with the coast, is a row of low elevations called hammocks, rising some ten or twelve feet above the surface of the swamp, the mountains of that district ; and these, on examination, are found to be still older coral reefs, carrying back our chronology another 6,000 years. Beyond these there is still another row, making 24,000 years.

The distance from the outer reefs to those last named is fifteen miles. I am told by intelligent officers of the army who have explored the country to Lake Okeechobee, sixty miles inland, that it is all formed of series of coral reefs. In fact, the whole peninsula of Florida is a coral formation, and we are brought to the conclusion that hundreds of thousands of years have been consumed in its slow growth.

And yet this is to-day in the chronology of our globe. The polyps that have built up Florida belong to living species. In the divisions of geologists this is the present formation. When we examine rocks formed by extinct species, we are led to a knowledge of periods still more inconceivable, during which nature has been conducting her operations.

DISCUSSION ON GUNPOWDER.

At the regular weekly meeting of the Polytechnic Association of the American Institute on Thursday evening, January 30th, the discussion was resumed on the subject of the application of chemistry to the military art—this subject having been continued from the meeting of the previous week.

Prof. JOY—Three years ago Mr. Bunsen, Professor of Chemistry in the University of Heidelberg, examined with great care the products of the combustion of gunpowder, and as the results were quite different from the statements of our text books, an account of them may interest this meeting. Bunsen found that of the substances formed by the combustion of powder, 67.7 per cent are solid, and 31.24 per cent are gaseous. The following is his list of both classes :—

PRODUCTS OF THE COMBUSTION OF 100 LBS. OF POWDER.

Solids.		
Sulphate of potassa	42.20	
Carbonate of potassa	12.60	
Hyposulphite of potassa	3.20	
Sulphide of potassium	2.10	
Sulphocyanide of potassium	.30	
Nitrate of potassa	3.70	
Charcoal	.70	
Sulphur	.10	
Carbonate of ammonia	2.80	
		67.70
Gases		
Nitrogen	9.90	
Carbonic acid	20.10	
Carbonic oxide	.90	
Hydrogen	.02	
Sulphide of hydrogen	.18	
Oxygen	.14	
		31.24
Total		98.94

As so large a portion of the powder is formed by combustion into substances which are solid, the gun would soon be completely filled up and rendered useless, were it not that most of the solids are thrown out by the expansion of the gases. Bunsen states the pressure at 4,374 atmospheres, 1,000 of which are due to the expansion by heat.

Bunsen's analyses of the powder which he used showed it to be composed of the following substances ;

Nitrate of Potassa	79.99
Sulphur	9.84
Carbon	6.69
Hydrogen	.41
Oxygen	3.07
Total	100.00

Prof. SEELY—I would ask Prof. Joy if the account gives the mode in which the powder was burned ?